PROCEEDINGS, 49th Workshop on Geothermal Reservoir Engineering
Stanford University, Stanford, California, February 12-14, 2024
SGP-TR-227

Beyond Electricity: Geothermal Direct Use Business Models and Potential Applications in Indonesia

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Keywords: geothermal, direct use, direct utilization, Indonesia

ABSTRACT

The direct application/direct use of geothermal energy involves using the heat energy from the Earth's interior immediately, bypassing the need to convert it into electricity or other energy forms. This approach to harnessing geothermal energy is increasingly recognized for its sustainability and renewable nature, offering a promising solution to diverse energy requirements. However, the focus on utilizing geothermal resources has predominantly been on electricity generation, leaving the direct use of geothermal energy in areas beyond power production less explored. In Indonesia, despite its vast geothermal potential, the progress in developing direct use geothermal facilities has been minimal, with no significant developments reported since 2015. This is in stark contrast to the country's geothermal power generation sector, which ranks second globally in installed capacity, only behind the United States. This disparity suggests a notable oversight in the exploration of geothermal energy for direct applications in Indonesia.

This study aims to explore and analyze potential business models that could utilize geothermal energy for direct use in Indonesia, along with assessing the feasibility of these applications across various geothermal regions within the country. By employing research methodology that includes reviewing existing literature, conducting case studies, and interviewing industry experts, the study seeks to gather in-depth insights into the current state and future possibilities of geothermal direct use. An essential part of this research involves examining Indonesia's regulatory and policy landscape surrounding geothermal energy, identifying both barriers and opportunities for the development of direct use projects. The analysis underscores the importance of establishing supportive policies, offering incentives, and fostering stakeholder collaboration to encourage the expansion of geothermal direct use initiatives.

Additionally, the study explores various business models for geothermal direct use especially for commercial purpose. The findings of this study are intended to lay a foundational groundwork for policymakers, investors, and industry stakeholders to recognize and leverage the untapped potential of geothermal energy for direct use in Indonesia, potentially leading to a more diversified and sustainable energy sector.

1. INTRODUCTION

1.1. Geothermal Energy Status in Indonesia at a Glance

Geothermal energy, harnessed from the Earth's internal heat, stands out as a promising and sustainable power source that aligns seamlessly with the global transition towards cleaner and renewable energy alternatives. Given its immense geothermal potential, Indonesia has emerged as a focal point for geothermal exploration and development, showcasing the nation's unwavering commitment to curbing carbon emissions and ensuring energy security. Geothermal energy development possesses inherent traits of being environmentally friendly, with low carbon emissions, although requiring substantial initial investments and featuring an extended period for returns. Hence, it is imperative for both investors and geothermal developers to effectively oversee and manage their projects (Al Asy'ari, Adityatama, & Purba, 2023; Al Asy'ari, et al., 2022). As the world grapples with the urgent imperative of addressing climate change, unlocking the full potential of geothermal energy becomes nothing short of crucial.

Indonesia, situated within the Pacific Ring of Fire, is graced with abundant geothermal potential due to its tectonic activity and volcanic landscapes. Indonesia, renowned for its abundant geothermal reserves approximately 23,060.4 MW ~ 23 GW (EBTKE, 2024a; EBTKE, 2022). Based on Thinkgeoenergy (2023), Indonesia is currently become 2nd largest geothermal producer countries with total installed capacity is approximately 2,417.3 MW. The current updated information of geothermal powerplant installed capacity worldwide is shown in Figure 1.

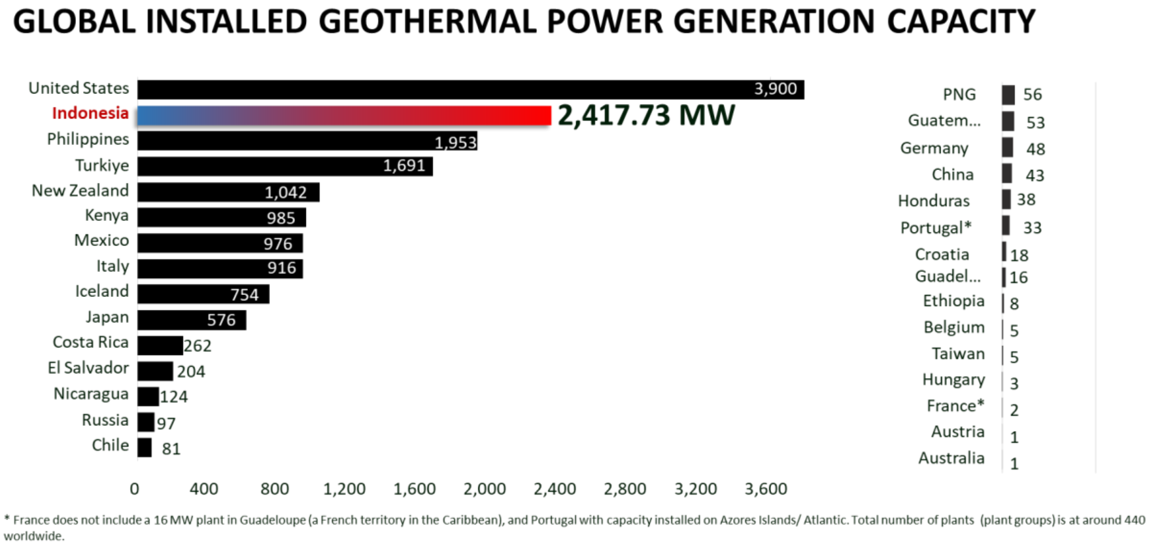

Figure 1: Worldwide update geothermal power plant installed capacity as per January 2024. Modified design from (Thinkgeoenergy, 2024; Thinkgeoenergy, 2023; Richter, 2023)

This geothermal wealth positions Indonesia as one of the world's leading geothermal energy producers and provides a unique opportunity to explore diverse applications beyond conventional power generation. The nation's geothermal landscape, rich and vast, offers opportunities that extend beyond the traditional confines of electricity generation. Despite this wealth of resources, the current installed capacity of 2,417.3 MW reflects just 10.48% exploitation of the available geothermal potential (EBTKE, 2024). This disparity underscores a substantial reservoir of untapped energy, suggesting a significant margin for growth in Indonesia's energy infrastructure.

Looking ahead, the Government of Indonesia has outlined an ambitious trajectory for geothermal development. By the year 2030, the goal is to achieve an installed capacity of 5,799 MWe, as delineated in the RUPTL 2021-2030 plan (PLN, 2021a). This target necessitates a substantial expansion of 3,381.27 MWe over the next six years, a pace that would demand a significant acceleration to an average annual addition of 375.7 MWe. This indicates a vast untapped resource that could significantly contribute to the nation's energy mix, reducing reliance on fossil fuels and enhancing sustainability.

The graphical representation in Figure 2 illustrate this strategic vision, where the dotted blue line indicates the projected growth required to meet the 2030 target. This trajectory not only symbolizes Indonesia's commitment to sustainable energy but also highlights the pivotal role of geothermal power in reducing the nation's carbon footprint and diminishing its dependence on fossil fuels.

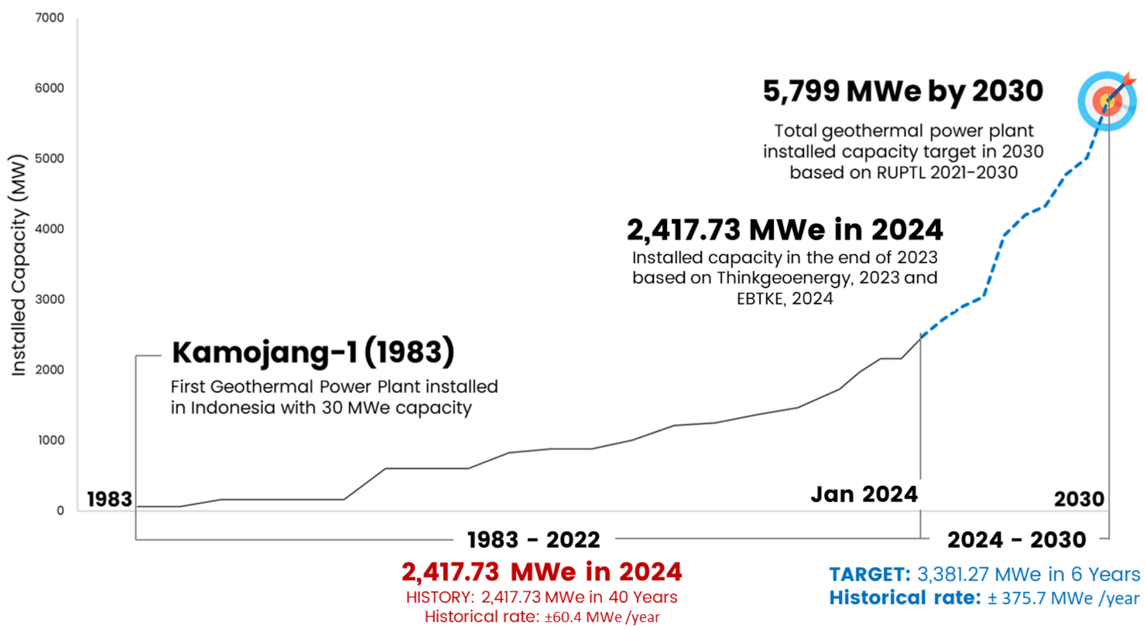

Figure 2: Indonesia Geothermal installed capacity update and 2030 target. Modified from (EBTKE, 2024; Al Asy'ari M. R., Adityatama, Tobing, Siregar, & Purba, 2023; PLN, 2021a)

As the Indonesian government forges ahead with its 2030 vision, the geothermal sector is poised to become an even more critical component of the nation's energy mix. The path forward involves concerted efforts from stakeholders across the board, encapsulating a synergy between technological advancements, policy frameworks, and sustainable investment strategies.

This country has potential and opportunities to exploit geothermal energy not only for electricity generation but also for direct-use applications. Geothermal direct use involves harnessing the naturally occurring heat from geothermal reservoirs for various purposes beyond power generation. These applications encompass district heating, greenhouse cultivation, industrial processes, and even aquaculture. As the demand for sustainable energy solutions continues to surge, the exploration of these diverse direct-use applications becomes nothing less than imperative.

While geothermal power generation has received considerable attention, the possibilities presented by geothermal direct use remain relatively untapped. This study seeks to illuminate this underexplored potential, with a focus on the myriad benefits, challenges, and business models associated with harnessing geothermal energy directly.

However, realizing the full potential of geothermal direct use requires concerted efforts from various stakeholders. Policymakers must provide a supportive regulatory framework that facilitates project development and ensures fair allocation of risks and rewards. Investors need to recognize the long-term benefits and opportunities presented by geothermal direct use projects. Communities and end-users play a crucial role in embracing these solutions and reaping the benefits they offer.

1.2. Research Background

Indonesia's geothermal capacity is a testament to its natural endowment, with the country's volcanic geography contributing to an estimated 23,060 MW of geothermal potential (EBTKE, 2024).Despite Indonesia's vast geothermal energy potential, its utilization for geothermal direct applications remains significantly smaller compared to other countries.There have been minor updates regarding new geothermal direct utilization facilities in Indonesia since 2015.

Globally, Indonesia ranks as the second-highest geothermal producer, with an installed capacity of 2,417.73 MW, following closely behind the United States (Thinkgeoenergy, 2024). This rank reflects a significant achievement in geothermal power generation. Yet, when it comes to the direct utilization of geothermal resources, Indonesia occupies the 74th position among 88 surveyed countries, with a mere 2.3 MW of installed thermal capacity dedicated to direct uses (Lund & Toth, 2021)This contrasts sharply with the nation's geothermal electricity generation prowess and indicates a substantial gap between potential and actualized utilization in non-electric domains.

In the context of global geothermal direct use, China leads the way with an impressive 14,160 MW of installed capacity, setting a benchmark for other nations. The disparity is striking when compared to Indonesia's underutilization, particularly considering the significant geothermal resources at its disposal. The illustration in Figure 3 portrays the latest international and Indonesian statistics on geothermal direct use, spotlighting Indonesia's lag in this sector. This underutilization is notable, especially given the absence of substantial updates or expansions in Indonesia's geothermal direct use infrastructure since 2015.

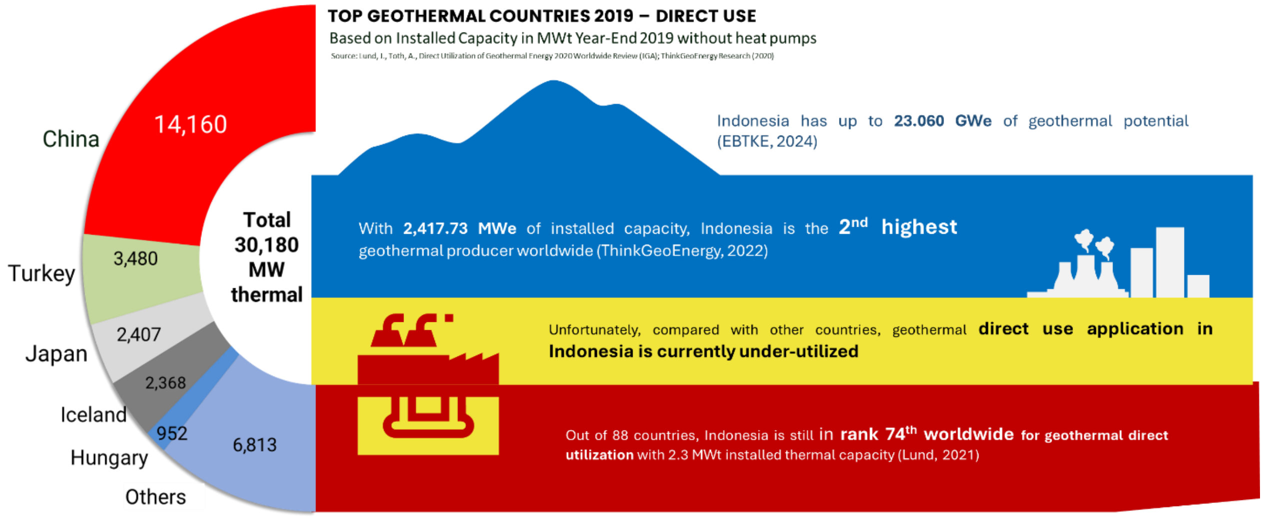

Figure 3: Latest Worldwide and Indonesia geothermal direct use (GRG-Geoenergis, 2024; Bagaskara, et al., 2023; Richter, 2023; Lund & Toth, 2021).

The juxtaposition of Indonesia's strong position in geothermal electricity generation against its modest direct use applications underscores a divergence in focus. It highlights a sector that, if nurtured, could enhance the country's energy sustainability and diversify its applications of geothermal resources. As Indonesia continues to harness its geothermal resources predominantly for electricity, the potential for direct applications remains largely untapped. Addressing this imbalance could not only increase the efficiency of the nation's geothermal resource utilization but also contribute to a more diversified and resilient energy sector.

Despite the potential of geothermal direct use in Indonesia, there exists a research gap regarding its applications and business models in the Indonesian context. One of major solution for boosting geothermal direct use application in Indonesia is develop the direct use business in commercial scale.

1.2. Research Objectives and Methods

This preliminary study delves into the geothermal direct-use business models and their potential applications at various sites across Indonesia. It encompasses the identification and analysis of viable business models that could leverage geothermal energy for direct applications within the country. The objectives of this study are twofold:

- To investigate the global and Indonesian landscapes of geothermal direct use applications.
- To explore the array of business models that could facilitate the implementation of geothermal direct use projects.

Through simple analysis, this paper aims to contribute to the discourse on sustainable energy utilization and assist stakeholders in making informed decisions regarding the integration of geothermal direct use into Indonesia's energy mix. As Indonesia pursues its renewable energy targets, the exploitation of geothermal direct use holds promise for spurring economic growth and fostering a more environmentally responsible energy sector.

By analyzing these elements, this paper aims to contribute to the broader discourse on sustainable energy utilization and help stakeholders make informed decisions about integrating geothermal direct use into Indonesia's energy portfolio. As the nation embarks on a path towards achieving its renewable energy targets, harnessing the untapped potential of geothermal direct use promises not only to drive economic growth but also to establish a more environmentally responsible energy sector.

The journey towards a greener energy landscape may be challenging, but the rewards are abundant. By embracing applicable business models, tapping into potential geothermal working areas, and addressing challenges head-on, Indonesia can unlock the full potential of geothermal direct use. As we look ahead, this paper is expected to become one of a steppingstone towards realizing a more resilient, prosperous, and sustainable future, where geothermal energy stands as a beacon of progress and possibility.

2. GEOTHERMAL DIRECT USE AT A GLANCE AND ITS STATUS

In the realm of indirect use, geothermal heat is harnessed to generate electrical power. This process typically involves an energy center where geothermal fluids are drawn from a production well, their heat energy is converted to electricity, and the cooled fluids are then returned to the earth's crust via a reinjection well. This cycle facilitates a sustainable generation of electricity while maintaining the balance of geothermal reservoirs. Conversely, the direct use of geothermal resources involves utilizing the heat energy or fluid from these resources without an intermediary conversion process. The direct use of geothermal resources is the use of the heat energy or the fluid from geothermal resources without intervening medium as opposed to its conversion to other forms of energy such as electrical energy and refer to all applications where the commodity of value is extracted directly from geothermal fluids from heat, minerals, and gases (ESMAP, 2022)

The Figure 4 illustrates direct uses of geothermal energy, which extend far beyond electricity generation, highlighting their potential to broaden the utilization scale various industries. For instance, district heating can exploit geothermal heat for residential space heating and cooling, offering a sustainable alternative to conventional methods, particularly in Indonesia's urban areas. Greenhouse cultivation is another application, where geothermal heat can boost agricultural productivity in controlled environments, presenting a viable solution for year-round cultivation irrespective of external weather conditions. Moreover, industrial processes can incorporate geothermal energy for tasks such as drying agricultural products or desalinating water, thereby reducing their carbon footprint. The aquaculture industry is also poised to benefit, with geothermal heat serving to optimize conditions for fish farming, ensuring ideal water temperatures to promote growth and health of aquatic life.

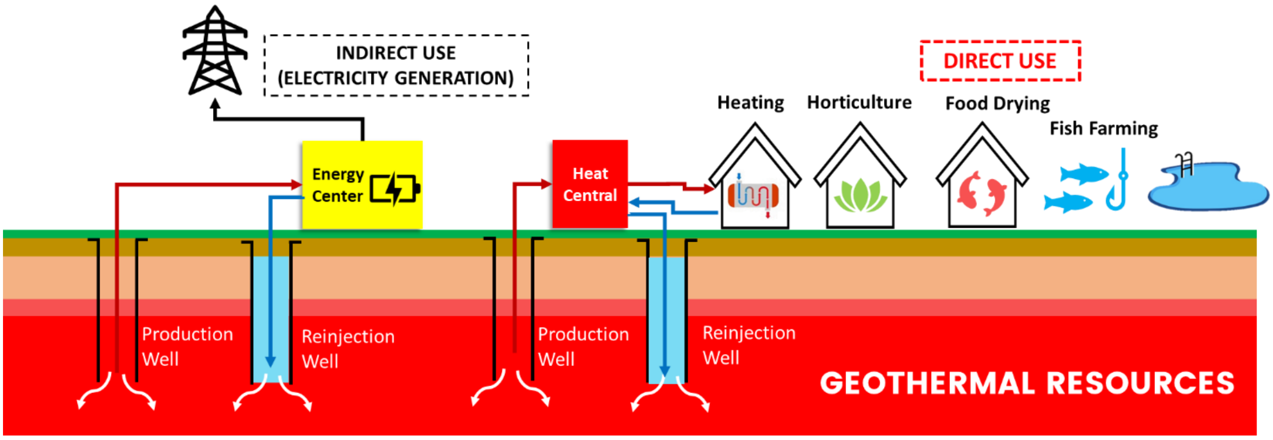

Figure 4: Simplified illustration of the geothermal indirect use (power generation) and direct use. Modified from (Hallgrimsdottir, 2021)

Geothermal direct use can be categorized based on the heat energy sources as illustrated in Figure 5. Geothermal surface manifestations are visible expressions of geothermal energy, such as hot springs and fumaroles. These features can be harnessed directly for uses in balneology, tourism, and small-scale local heating. Excess steam and heat, often a byproduct of geothermal power plants, represent an efficient use of energy that would otherwise be wasted, facilitating applications like district heating or industrial drying processes.

Shallow drilled wells access geothermal energy closer to the Earth's surface and are typically used for lower temperature applications. Conversely, deep wells tap into higher temperature reservoirs and are capable of supporting a range of uses from electricity generation to high-temperature industrial processes.

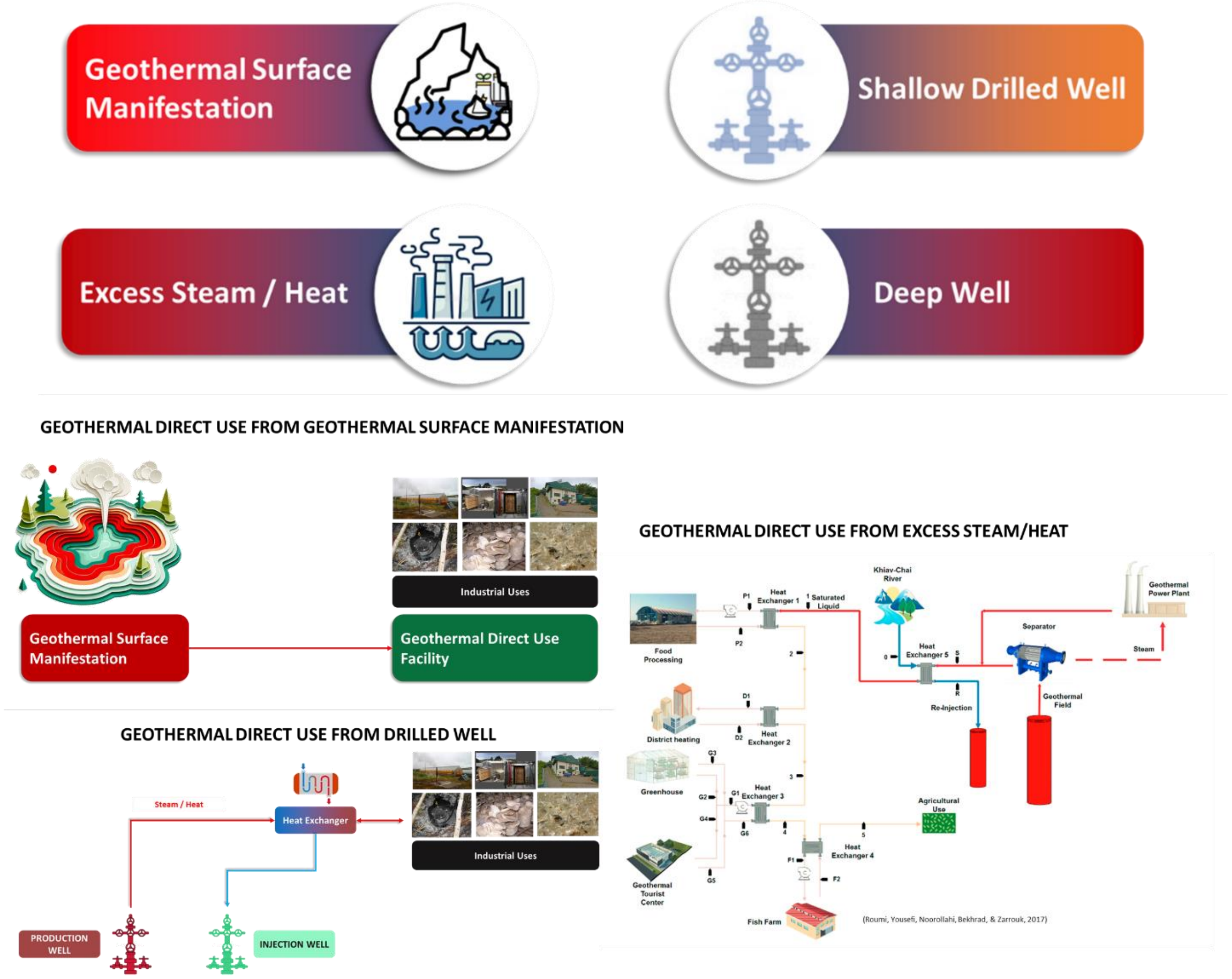

Figure 5: Illustration of Typical geothermal direct use heat energy sources and simplified scheme (GRG-Geoenergis, 2024; ESMAP, 2022; Hallgrimsdottir, 2021; Roumi, Yousefi, Noorolahi, Berkhrad, & Zarrouk, 2017).

Geothermal direct use, an emerging facet of geothermal utilization, involves harnessing the heat directly from geothermal reservoirs for non-electric applications. As the world seeks to decarbonize its energy systems and combat climate change, understanding and harnessing geothermal direct use becomes imperative. This sub-section delves into the background and reviews existing literature surrounding geothermal direct use applications and their potential in Worldwide and Indonesia.

Geothermal direct use applications encompass a diverse range of sectors that can benefit from harnessing the Earth's heat directly. The typical geothermal direct use applications and their potential implications for Indonesia is described below:

- **District Heating:**

  District heating involves distributing geothermal heat through a network of pipes to provide space heating and cooling for residential, commercial, and industrial buildings. In Indonesia, where urban centers experience both energy demand and environmental concerns, geothermal district heating could emerge as an efficient and eco-friendly solution. By displacing fossil fuel-based heating systems, geothermal district heating could significantly reduce greenhouse gas emissions and enhance energy efficiency.

  District heating systems powered by geothermal energy have gained popularity in countries such as United States, Iceland and Sweden. The Reykjavik district heating system in Iceland, for instance, utilizes geothermal resources to provide heating for over 90% of its buildings, moreover in Iceland also apply the integrated/cascaded uses for other direct use application. Similarly, the city of Stockholm in Sweden has successfully integrated geothermal energy into its district heating network, reducing carbon emissions and dependence on fossil fuels.

- **Greenhouse Cultivation:**

  Geothermal energy can be channeled to provide a controlled environment for greenhouse cultivation. By maintaining optimal temperatures for plant growth, geothermal heat can extend growing seasons, increase crop yields, and improve the quality of produce. Indonesia's rich agricultural landscape makes greenhouse cultivation a compelling application, particularly for enhancing food security and promoting sustainable farming practices.

Geothermal energy has revolutionized greenhouse cultivation in various regions. The Netherlands has embraced geothermal-powered greenhouses, allowing farmers to control temperatures and create optimal growing conditions year-round. This innovative approach has increased crop yields and reduces the need for conventional heating methods.

- **Industrial Processes:**

  Industries rely heavily on heat for various processes, including drying, pasteurization, and sterilization. Geothermal energy can be integrated into industrial operations, reducing reliance on fossil fuels and lowering operating costs. Industries such as food processing, paper production, and textile manufacturing could potentially benefit from geothermal heat, resulting in both economic and environmental gains.

  Countries like the United States and Turkey have harnessed geothermal energy for industrial processes. The Oregon Institute of Technology in the U.S. operates a successful geothermal industrial park, where businesses benefit from the availability of geothermal heat for manufacturing and production. In Turkey, the Tuzla industrial zone utilizes geothermal energy for heating, cooling, and drying processes.

- **Aquaculture and Fish Farming:**

  Geothermal direct use can be harnessed to optimize conditions for aquaculture and fish farming. Maintaining specific water temperatures can enhance fish growth rates, reduce mortality rates, and improve overall fish health. Indonesia's thriving aquaculture industry, particularly in regions with geothermal resources, presents an opportunity to revolutionize fish farming practices by utilizing geothermal heat.

  In Hungary, the town of Hévíz uses geothermal water to cultivate fish in temperature-controlled environments. This practice has resulted in higher fish yields and improved fish health.

Each of these geothermal direct use applications holds significant promise for Indonesia's sustainable development. By diversifying the utilization of geothermal energy, the country can address multiple challenges, including energy security, greenhouse gas reduction, job creation, and economic growth. However, it's important to acknowledge that while the potential benefits are compelling, successful implementation requires addressing technical, regulatory, and financial considerations.

2.1. Global Direct Use Applications Status

The adoption of geothermal energy for direct use applications has been gaining momentum worldwide as nations seek to transition to cleaner and more sustainable energy sources. Several countries have made significant strides in implementing geothermal direct use projects, showcasing the versatility and potential of this approach. Figure 6 illustrate the current global geothermal direct use application status (Richter, 2023; Lund & Toth, 2021)

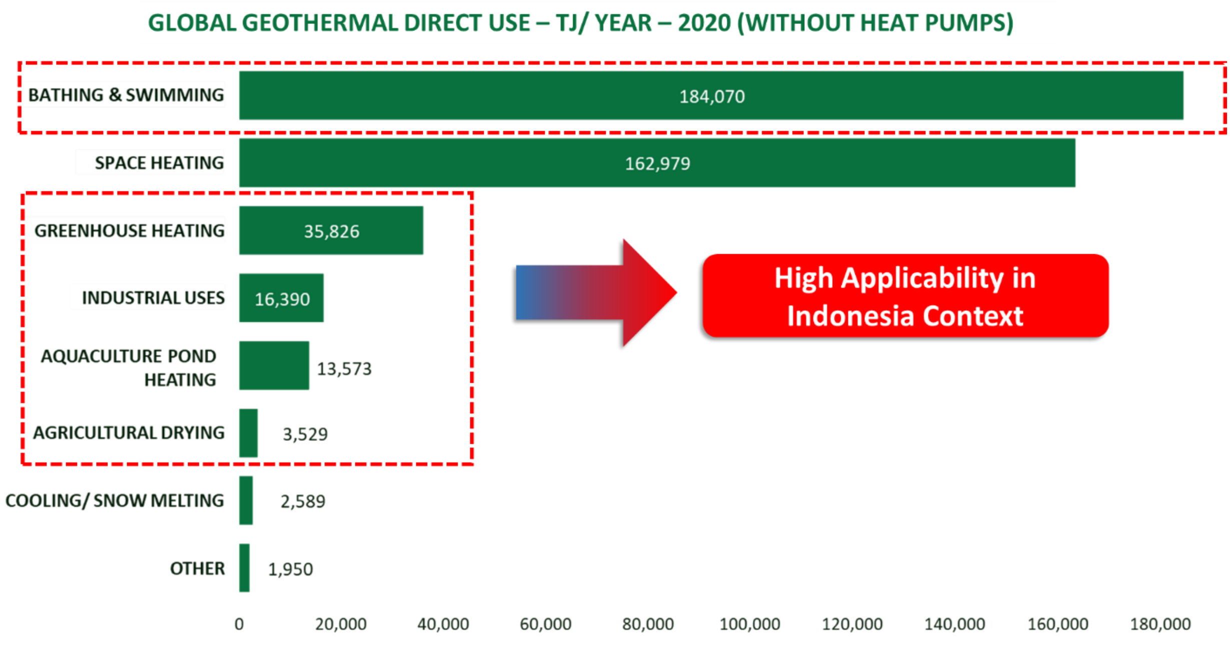

Figure 6: Current global geothermal direct use application status. Modified design from (Richter, 2023; Lund & Toth, 2021)

As illustrated in Figure 6, the leading applications of geothermal direct use are for bathing and swimming, and space heating, which together constitute the bulk of global usage. Specifically, bathing and swimming account for 184,070 terajoules per year (TJ/year), while space heating represents 162,979 TJ/year. These applications demonstrate the immediate and tangible benefits of geothermal energy, providing comfort and warmth without intermediate conversion to electricity.

Highlighted within the image are applications that possess high applicability in the Indonesian context. Greenhouse heating, with 35,826 TJ/year, emerges as a significant use, suggesting potential for further development in Indonesia's agricultural sector. Industrial uses and aquaculture pond heating, with 16,390 TJ/year and 13,573 TJ/year respectively, are also notable for their substantial energy consumption. These sectors present opportunities for Indonesia to integrate geothermal heat into industrial processes and aquaculture, potentially enhancing productivity and sustainability.

The global trend towards the adoption of geothermal energy for direct use, reflects a growing recognition of its potential in contributing to a transition towards cleaner, more sustainable energy sources (Richter, 2023; Lund & Toth, 2021). Countries are increasingly investing in geothermal direct use projects, exploring the breadth of their applications.

Based on Thinkgeoenergy forecast, it is expected that there will be significant growth from 2020 to 2030 with total 470,000 TJ or equivalent with 212% (Richter, 2023). The forecast of global geothermal direct use is shown in Figure 7.

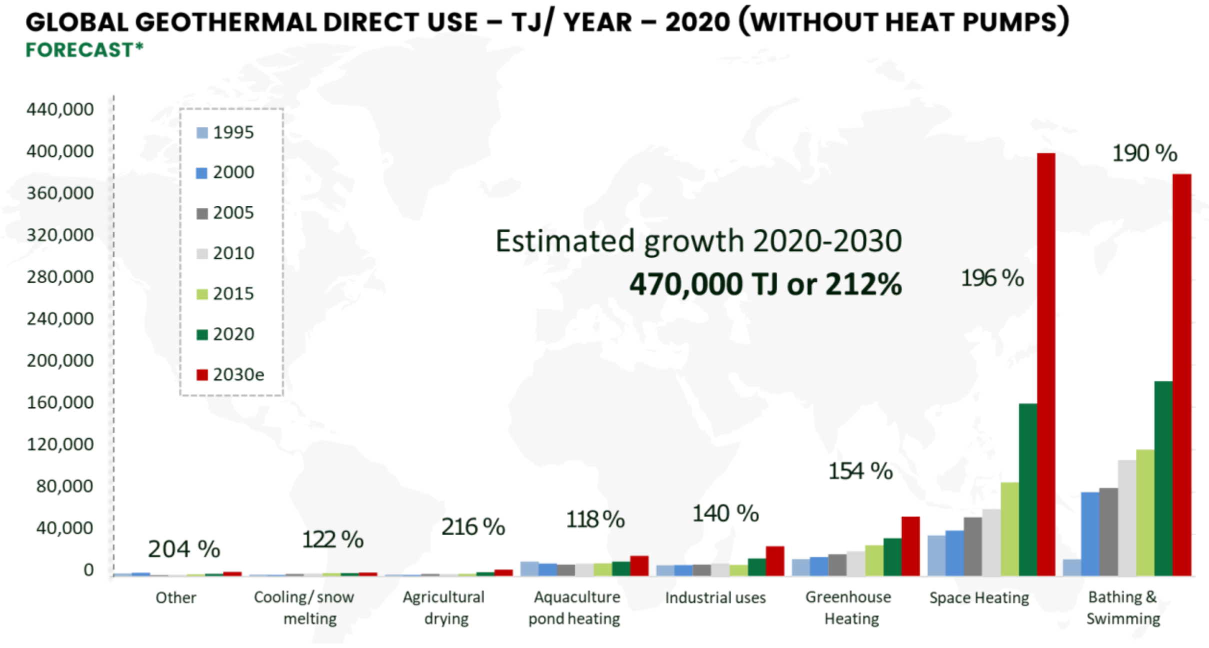

Figure 7: Global geothermal direct use forecast. Base data source from (Lund & Toth, 2021) and forecast Data from (Richter, 2023)

Agricultural drying and other niche applications, such as cooling and snow melting, collectively contribute to the spectrum of direct uses, showcasing the adaptability of geothermal energy. These categories, while smaller in scale, highlight the innovative ways geothermal resources can be applied beyond conventional heating.

The anticipated surge in utilization speaks to the robust potential of geothermal energy to play a central role in the future energy landscape. It also suggests a pivotal shift towards more sustainable and environmentally friendly energy solutions, resonating with global efforts to address climate change.

2.2. Indonesia Current Direct Use Status

In Indonesia, the business model for geothermal direct use (GDU) has predominantly been based on Corporate Social Responsibility (CSR), the example of the business is shown in Figure 8. This means that companies engage in GDU projects as a part of their commitment to social responsibility rather than as a core business venture. CSR projects are generally small-scale and designed to address specific community needs or to enhance a company's public image. They may not aim for long-term sustainability or extensive development. As these projects are often secondary to a corporation's primary business objectives, they may lack comprehensive planning and substantial investment needed for large-scale GDU development.

Moreover, the geothermal direct use with CSR type might has financial constraints, the CSR budgets are typically constrained and are not intended for substantial investment in infrastructure and technology. Since CSR projects are not driven by profit, they may not attract additional investment or financial support from other stakeholders. As a results from this hypothesis, the current geothermal developer is reluctant to significantly develop the geothermal direct use.

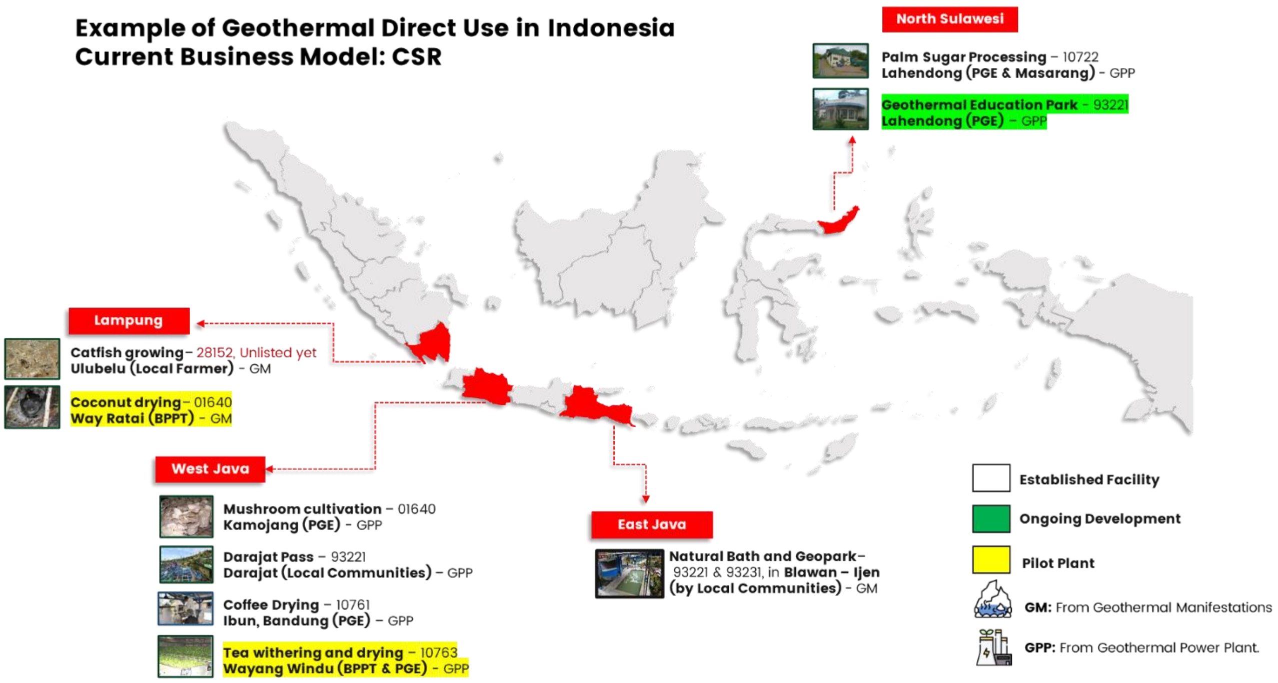

Figure 8: Example of geothermal direct use application in Indonesia.

Based on the worldwide review on the geothermal direct use application, the potential application that might be applicable for Indonesia context especially in commercial use is summarized below:

- Greenhouses and Agricultural Applications: Agriculture plays a significant role in Indonesia's economy, and the integration of geothermal energy can revolutionize this sector. Geothermal heating in greenhouses can enable year-round cultivation, improving crop yield and quality. The constant supply of heat from geothermal sources can create optimal growing conditions, particularly for temperature-sensitive crops. Additionally, geothermal energy can be employed for crop drying, reducing post-harvest losses and energy costs.

- Industrial Processes: Indonesia's growing industrial sector could benefit from the adoption of GDU. Several industrial processes require significant heat, such as in the food and beverage industry for pasteurization and drying, or in the textile industry for dyeing and processing. By utilizing geothermal heat, industries can reduce operational costs and minimize greenhouse gas emissions. The proximity of some industrial zones to geothermal resources makes this application particularly appealing.

- Aquaculture: Indonesia, as one of the world's largest fish producers, holds great potential for applying geothermal energy in aquaculture. Heating aquaculture ponds with geothermal energy can maintain optimal water temperatures, accelerating fish growth and enhancing production. This practice can be particularly valuable for species that require specific temperature ranges, offering a sustainable and efficient solution.

- Spas and Recreational Facilities: The natural hot springs found in various regions of Indonesia provide an opportunity for therapeutic and recreational facilities. Developing geothermal spas could boost tourism and offer health benefits. Moreover, geothermal energy could be used to heat swimming pools and other recreational facilities, adding value to the hospitality industry.

Indonesia's geothermal potential offers diverse opportunities for direct use applications, ranging from agriculture to industrial processes to recreation. While some of these applications are still in the exploratory phase, they represent viable avenues for sustainable development. Leveraging geothermal energy aligns with Indonesia's commitment to renewable energy and provides a pathway to enhance various sectors of the economy. Partnerships between government, industry, and research institutions will be key to realizing the full potential of geothermal direct use in the country.

Currently, Indonesia has already several regulations that regulate the geothermal direct use business in Indonesia. Bagaskara et al (2023) already summarize each applicable regulation that currently applied in Indonesia. The latest one that might be concerned is regulation of Minister of Energy and Mineral Resources Regulation No. 5 of 2021 regarding Standards for Business Activities and Product in the Implementation of Risk Based Business.

Simply, this law governs the standards related to geothermal business licensing for direct utilization, encompassing the requirements for KBLI (*Klasifikasi Baku Lapangan Usaha Indonesia*) licensing through the relevant ministries or institutions, the general business prerequisites in the form of SLO (*Surat Layak Operasi*), and the procedures for obtaining such an SLO. The illustration and list of KBLI is shown in Figure 9 below. However, not all the direct use business application types are listed on the regulation.

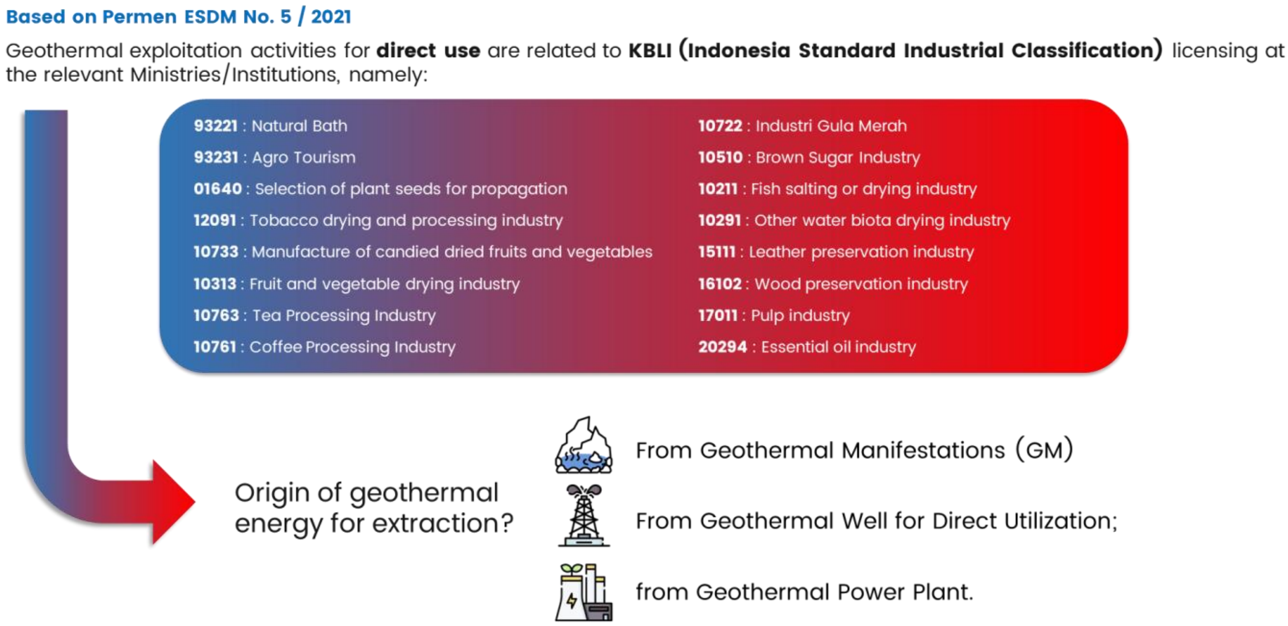

Figure 9: Indonesia Standard Industrial Classification (KBLI) for geothermal direct use business.

Indonesia also has already clear geothermal direct use business requirements as detailed in MEMR Regulation Number 5/2021. The application for the geothermal direct utilization operating certificate must be submitted to the Directorate General responsible for geothermal, or to the relevant provincial or district/city level service, as per their jurisdiction. This can be done in writing or through the Online Single Submission (OSS) system as illustrated in Figure 10. The required administrative documents generally consist of Business Identification Number/Permit (*Nomor Induk Berusaha*), a situation map of the geothermal energy location, and a copy of a proof/certificate indicating participation in training related to the direct use of geothermal energy from the businessperson.

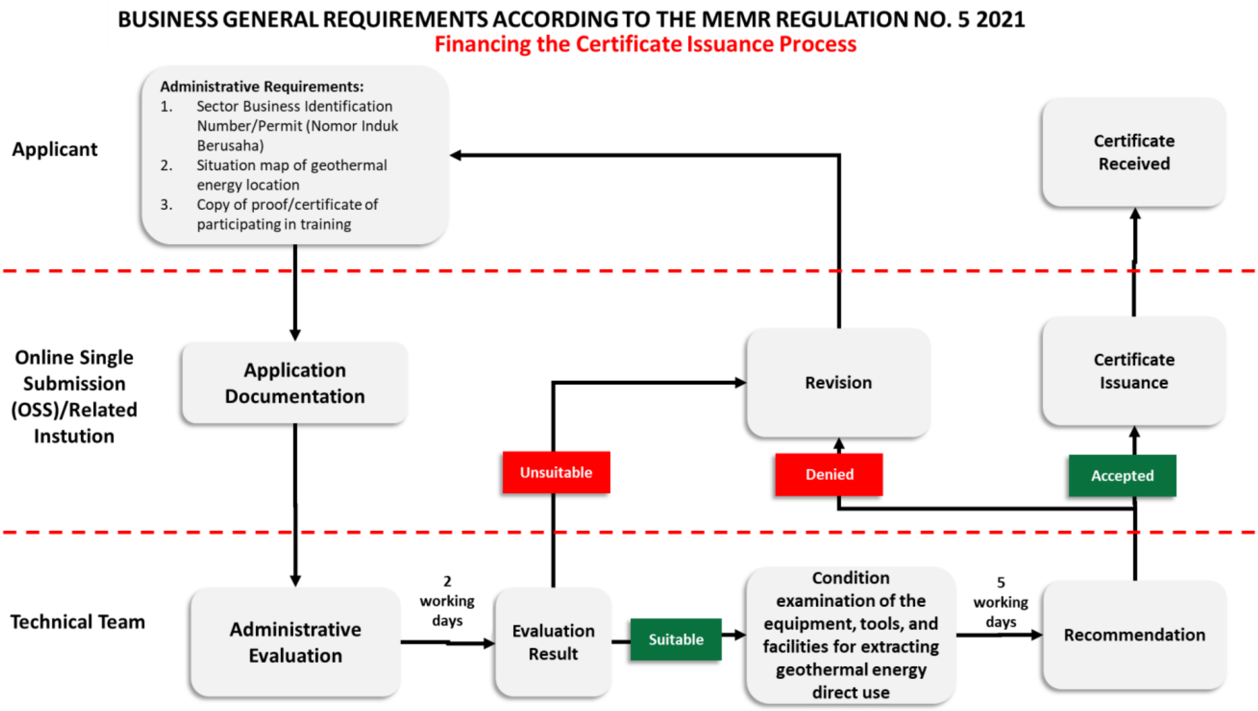

Figure 10: Business General Requirements According to The MEMR Regulation No. 5 2021 - Financing the Certificate Issuance Process

Moreover this regulation also already include the minimum amenities, facilities, and competencies that should be possessed by personnel involved in geothermal direct use as illustrated in Figure 11. In the realm of geothermal direct use, a distinct set of competencies is essential for personnel to ensure operational safety and efficiency. Firstly, individuals must possess a comprehensive understanding of the potential risks associated with geothermal manifestations such as hot springs, mud pools, steam grounds, and fumaroles. This knowledge forms the foundation for implementing safety measures and conducting operations without harm to humans or the environment.

Workers should be conversant with the equipment necessary for navigating and operating within these geothermal environments. Mastery over such equipment is crucial for the safe extraction of geothermal energy, whether from its natural manifestation or from the residual heat of indirect usage. Familiarity with the laws and regulations governing occupational health and safety, environmental protection, and management is non-negotiable. Adhering to these regulations not only ensures compliance but also fortifies the integrity and sustainability of geothermal exploitation processes.

Furthermore, the capability to manage work hazards and respond effectively to accidents is a requisite. This ability ensures that the extraction of geothermal energy, whether direct or indirect, does not compromise the wellbeing of personnel or the surrounding habitat.

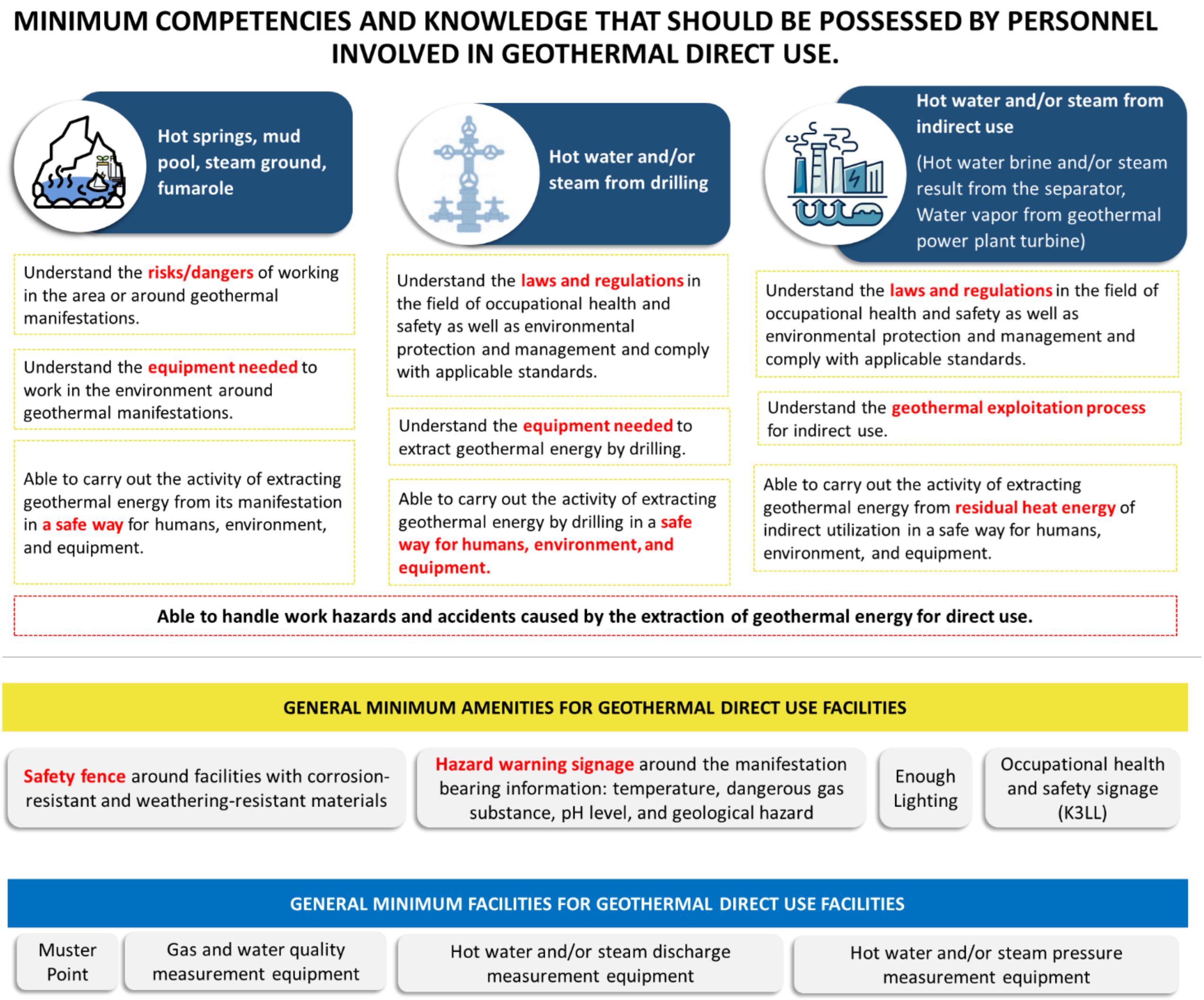

Figure 11: Minimum competencies that should be possessed by personnel involved in geothermal direct use, also general minimum amenities and supporting facilities for geothermal direct use site

Moreover, geothermal direct use facilities must be equipped with general minimum amenities. A safety fence constructed with corrosion-resistant and weathering-resistant materials is fundamental to demarcate and secure the site. Hazard warning signage is crucial to inform about onsite risks, including temperature extremes, gas emissions, pH levels, and geological hazards. Proper lighting and occupational health and safety signage must be omnipresent to maintain a secure working environment.

Lastly, the facilities should be outfitted with essential equipment. This includes muster points for emergency assembly, gas and water quality measurement tools, and equipment to monitor the discharge and pressure of hot water and steam. These instruments are indispensable for maintaining operational standards and ensuring the safety and efficiency of the geothermal direct use site. By combining these competencies with the necessary amenities and facilities, geothermal direct use sites can achieve operational excellence while prioritizing safety and sustainability.

3. GEOTHERMAL DIRECT USE BUSINESS MODELS

3.1. Geothermal direct use business model at a glance

Geothermal direct use (GDU) encompasses a broad spectrum of applications, ranging from heating and cooling of buildings to supporting various industrial processes, enhancing agricultural outcomes, and providing recreational amenities. The array of applications necessitates a diverse set of business models tailored to different market dynamics, regulatory frameworks, technological landscapes, and community exigencies. Predominantly, these business models can be classified into two main types, as delineated in Table 1 below.

Table 1. Typical geothermal direct use business models

Models Category	GDU Business Model	Brief Explanation
Traditional Business Models	Corporate Social Responsibility (CSR) based Model:	CSR-based models involve companies investing in GDU as a part of their social responsibility initiatives. While admirable, this model may limit the scalability and sustainability of geothermal projects, as it primarily focuses on community benefits rather than profit.
	Government-Led Models:	Governments can invest in geothermal projects, either through public funding or public-private partnerships (PPPs). This approach often aims to achieve energy security and environmental goals.
	Private Investment Models:	Private companies can invest in GDU projects to create profit-driven ventures. This model typically seeks high returns on investment and might require significant capital, technology, and risk management. This model of direct ownership entails an entity, such as a municipality or private company, owning and operating the geothermal direct use facility. In this model, the entity assumes full responsibility for project development, financing, and operation. Direct ownership offers maximum control and long-term benefits, including potential revenue generation and energy cost savings. However, it also entails higher upfront investment and risks.
Innovative Business Model	Community Ownership Models:	In this model, local communities invest in and own geothermal projects, often through cooperatives or community funds. It fosters local engagement, sustainable development, and ensures that benefits are shared within the community.
	Hybrid Models / Public-Private Partnerships (PPPs):	Simply, this model combining features from different traditional models, hybrid models can foster collaboration between public, private, and community stakeholders. It can help in distributing risks and leveraging diverse funding sources. PPPs involve collaboration between the public sector (government) and private entities to develop and operate geothermal direct use projects. PPPs distribute risks and responsibilities between partners, allowing governments to leverage private sector expertise and financing. While PPPs can streamline project implementation and reduce public funding burdens, they require robust regulatory frameworks and clear allocation of risks and rewards.
	Energy Service Company (ESCO) Models:	Simply, ESCOs design, build, finance, own, and operate GDU projects, selling the thermal energy to end-users. It provides a one-stop solution and can be attractive for end-users who don't want to invest in owning and operating geothermal systems. ESCOs offer an alternative model where a specialized entity provides geothermal direct use services to end-users. Under this arrangement, the ESCO designs, finances, installs, and operates the geothermal facility, and the end-users pay for the delivered energy or services. ESCOs mitigate financial and technical risks for end-users, enabling them to adopt geothermal direct use without upfront capital investment. This model can accelerate adoption but requires effective contractual agreements and performance monitoring
	Green Financing and Impact Investing Models:	These models attract investment from parties interested in environmental benefits and social impact. They can leverage global interest in sustainable development and climate change mitigation.

It is important to note that the challenges and considerations of the geothermal direct use business model can be affected by various aspect. Distinct business models may necessitate specialized regulatory support, financial incentives, and institutional frameworks to flourish. The selection of a business model is often contingent upon technological sophistication, capacity for innovation, and the intended application of GDU. Engagement with local communities, alignment with social objectives, and cultural considerations are paramount to the success of these business models. Furthermore, variables such as funding accessibility, risk management strategies, and expected returns on investment are influential factors that will profoundly affect the selection and triumph of a business model.

The development of apt business models for GDU is a multifaceted and crucial endeavor to harness its full potential. Both conventional and novel business models play integral roles in this context, and their adoption should be reflective of the distinctive characteristics of the geothermal resources, market demand, communal requisites, and the regulatory milieu. Collaboration, innovation, and a commitment to overarching energy and environmental objectives are essential to nurturing successful geothermal initiatives across a variety of business frameworks.

The deployment of diverse business models has been instrumental in the execution of geothermal direct use projects. Energy Service Companies (ESCOs), for instance, have enabled businesses and communities to leverage geothermal heat without the burden of upfront capital expenditures. Public-Private Partnerships (PPPs) have fostered synergies between governmental bodies and private sector stakeholders, propelling project development forward. Moreover, international collaborations and scholarly endeavors have significantly contributed to the expansion of GDU. Entities such as the International Geothermal Association (IGA) and the Geo-Heat Center at the Oregon Institute of Technology have been at the forefront of promoting knowledge exchange, capacity development, and the dissemination of best practices.

The current global landscape of GDU applications underscores the viability and advantages of tapping into geothermal heat for a multitude of uses beyond mere electricity generation. Asthe momentum towards sustainable energy solutions gains pace globally, the advancements in GDU stand as a testament to the potential of geothermal energy. This progress serves as an exemplar for Indonesia and other countries endeavoring to exploit this inexhaustible and renewable energy source.

In short, selecting the right business model is a critical step in driving the adoption of geothermal direct use applications. Each model offers distinct advantages and challenges, and its appropriateness depends on the specific application, project scale, and local context. As Indonesia navigates its transition to sustainable energy solutions, embracing innovative business models will be instrumental in unlocking the full potential of geothermal direct use for the nation's benefit.

3.2. Geothermal Direct Use General Business Model Scenario

This research evaluates various general scenarios for the development of business models related to geothermal direct use. These models are delineated as follows:

1. Direct use facilities operated by geothermal power companies as part of their Corporate Social Responsibility (CSR) initiatives aimed at community development.
2. Direct use facilities run by geothermal power companies (geothermal developers) for commercial purposes. This encompasses two distinct schemes:
    - Scheme 1: Geothermal developers only sell steam, and the direct use facility is managed by third parties / other business.
    - Scheme 2: Geothermal developers manage end-to-end of direct use business from extraction to application/sales.

Each scenario presents unique dynamics and implications for the geothermal industry, from the synergistic benefits of CSR to the integrated business approaches of commercial exploitation. These frameworks are critical in understanding the breadth of strategies available for leveraging geothermal resources beyond conventional electricity generation. This preliminary study on the geothermal business model aims to provide insights into sustainable business practices and the potential for geothermal energy to contribute to both local community advancement and the broader commercial market.

3.2.1. Geothermal direct use facilities managed by geothermal power company for CSR / community development.

This form of geothermal direct use business is typically characterized by its commitment to sustainable energy solutions. It serves as a conduit for geothermal power companies to contribute positively to societal welfare through CSR programs, which are designed to enhance the quality of life within local communities. By harnessing geothermal energy in such a way, these companies not only demonstrate environmental stewardship but also endorse social responsibility.

Geothermal direct use facilities managed by geothermal power companies as part of Corporate Social Responsibility (CSR) or community development programs represent a strategic alignment of energy production with broader social and community goals (Fadhillah, et al., 2023). This approach not only taps into geothermal resources for power generation but also leverages the same to foster community well-being, empowerment, and sustainability.

Geothermal power companies may adopt direct use projects as part of their commitment to social responsibility. By investing in community-oriented projects, these companies signal a commitment to the broader well-being of the areas where they operate. Close collaboration with local communities ensures that projects are designed to meet genuine needs and priorities, fostering a sense of ownership and alignment with community values.

Geothermal direct use in the context of CSR can also promote awareness of geothermal energy and increase public literacy about this clean energy source. Furthermore, such implementation aligns with the United Nations Sustainable Development Goals (SDGs), particularly Goal 7, which targets ensuring access to affordable, reliable, sustainable, and modern energy for all. By utilizing geothermal energy, companies, including third parties, can manifest their commitment to sustainability and a reduced carbon footprint. This can enhance their reputation and foster positive relationships with stakeholders. Figure 12 illustrates the operational scheme of geothermal direct use facilities managed by geothermal power companies within the framework of Corporate Social Responsibility (CSR) or community development initiatives.

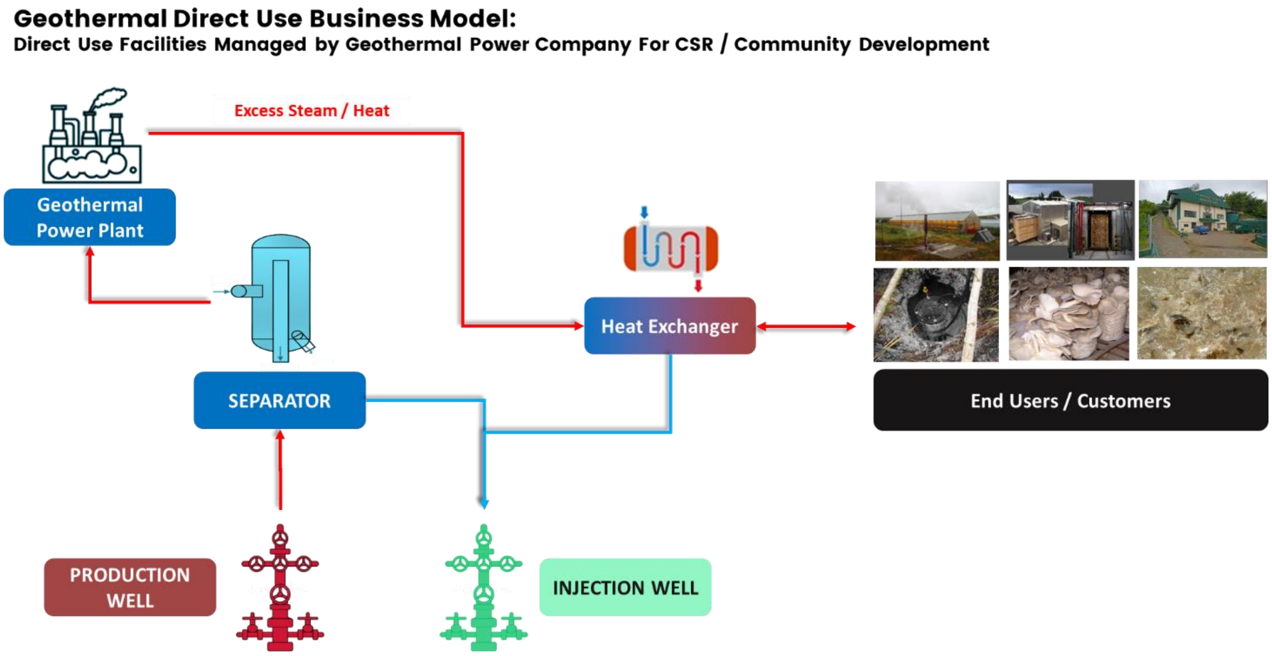

Figure 12: Illustration of direct use facilities managed by geothermal power company for CSR/community development.

The illustration of typical business model canvas of this CSR-based geothermal direct use business models is shown in Figure 13. This business model canvas illustrates how geothermal power companies can integrate CSR goals with their operational strategies. By leveraging geothermal direct use facilities, these companies can contribute to the social and economic development of local communities while promoting sustainable energy use. The comprehensive layout serves as a strategic guide for companies looking to align their energy production capabilities with broader social objectives, creating a synergy between business success and community development.

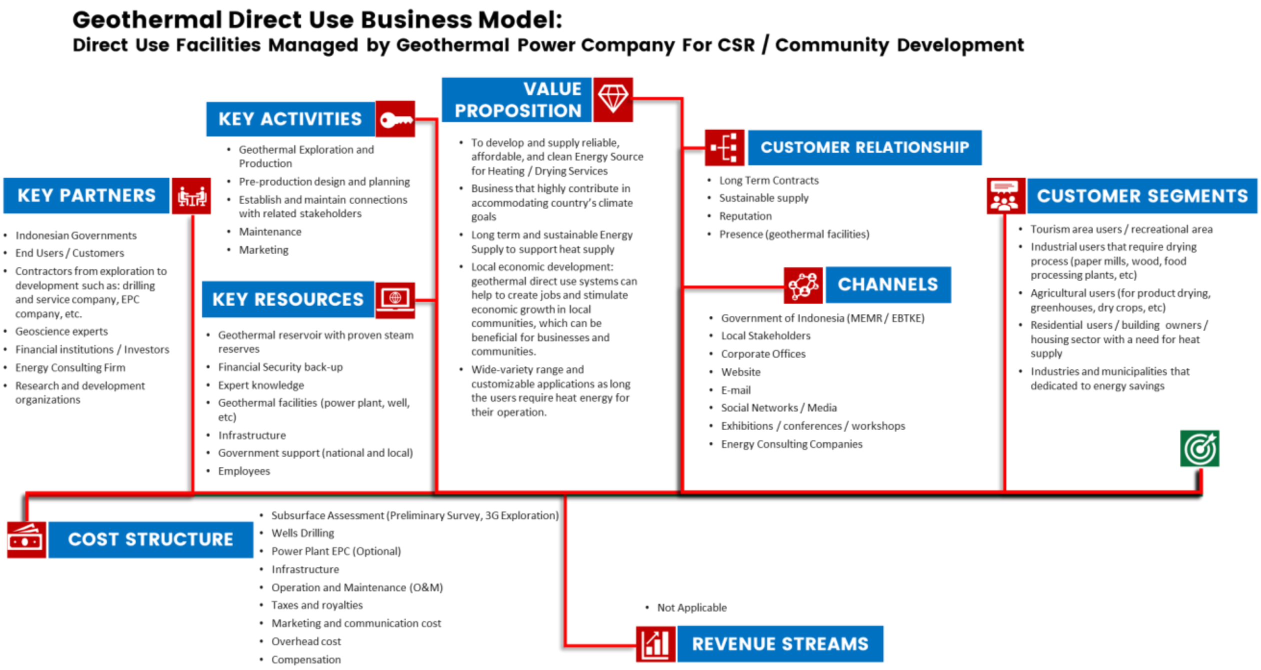

Figure 13: Typical business model of direct use facilities managed by geothermal power company for CSR/community development.

Geothermal direct use facilities managed by geothermal power companies for CSR and community development encapsulate a holistic approach to energy production and societal advancement. By weaving together commercial, environmental, and social threads, these projects have the potential to create multifaceted benefits that resonate with both local communities and broader sustainable development goals. Successful implementation requires a well-crafted strategy, meaningful collaboration, innovative thinking, and a deep commitment to shared values and objectives.

3.2.2. Geothermal direct use facilities managed by geothermal power company (geothermal developers) for commercial use.

Contrasting with the previous sub-section's emphasis on leveraging geothermal direct use for corporate social responsibility, this sub-section pivots towards the commercialization aspect. The primary aim is to generate additional revenue by commercializing heat energy, achievable through third-party collaborations or by the geothermal developer's own full-spectrum management, reaching customers directly. Capitalizing on the surplus heat or steam from a geothermal power plant can enhance operational competitiveness and contribute to a smaller environmental footprint.

Commercial direct use of geothermal energy can be adapted to meet the needs of businesses and industries located near geothermal resources. Common applications of this business model include, but not limited to:

- Providing process heat for manufacturing and industrial operations such as food and beverage production, textile manufacturing, and other industries that require high-temperature heat.
- Heating and cooling commercial buildings like offices, hotels, and malls.
- Supplying hot water for commercial swimming pools, hot springs, spa resorts, aquaculture, and other types of tourist attractions that require heat energy.
- Supporting other businesses that require heat energy as part of their services or processes.

A practical instance of commercial direct use under geothermal power company management is the application of geothermal fluids in the heating and cooling systems of data centers. Considering the substantial energy data centers consume for thermal management, geothermal energy emerges as a sustainable and dependable alternative. Additionally, the byproduct heat from these data centers can be repurposed for ancillary commercial uses, encompassing space heating, domestic hot water provision, and as a heat source for various industrial processes.

Another innovative example of commercial direct use applications is for desalination. This method can be employed to produce fresh water from saline water by using geothermal energy to heat the water. This heating makes it possible to separate salt and other minerals through evaporation or other processes, particularly beneficial in arid regions where fresh water is scarce (Gilang, Jauhari, & Kristiati, 2020). Overall, there is a diverse range of potential uses for direct use facilities operated by geothermal power companies. These facilities can offer businesses and other commercial operations environmentally friendly and economically viable energy solutions.

Scheme 1: Geothermal developers only sell steam, and the direct use facility is managed by third parties / other business.

This geothermal direct use scheme typically pertains to entities, other than geothermal power companies, directly utilizing geothermal energy sourced from the subsurface. The scope of heat energy application varies widely, from district heating to industrial and commercial processes.

The business models that related to geothermal direct use that managed by other entity of geothermal developers (third parties' company) can take various forms of models that depends on specific application and goals both the geothermal developers and third parties. The general illustration scheme of this direct use business model is shown in Figure 14 and the typical business model canvas is shown in Figure 15.

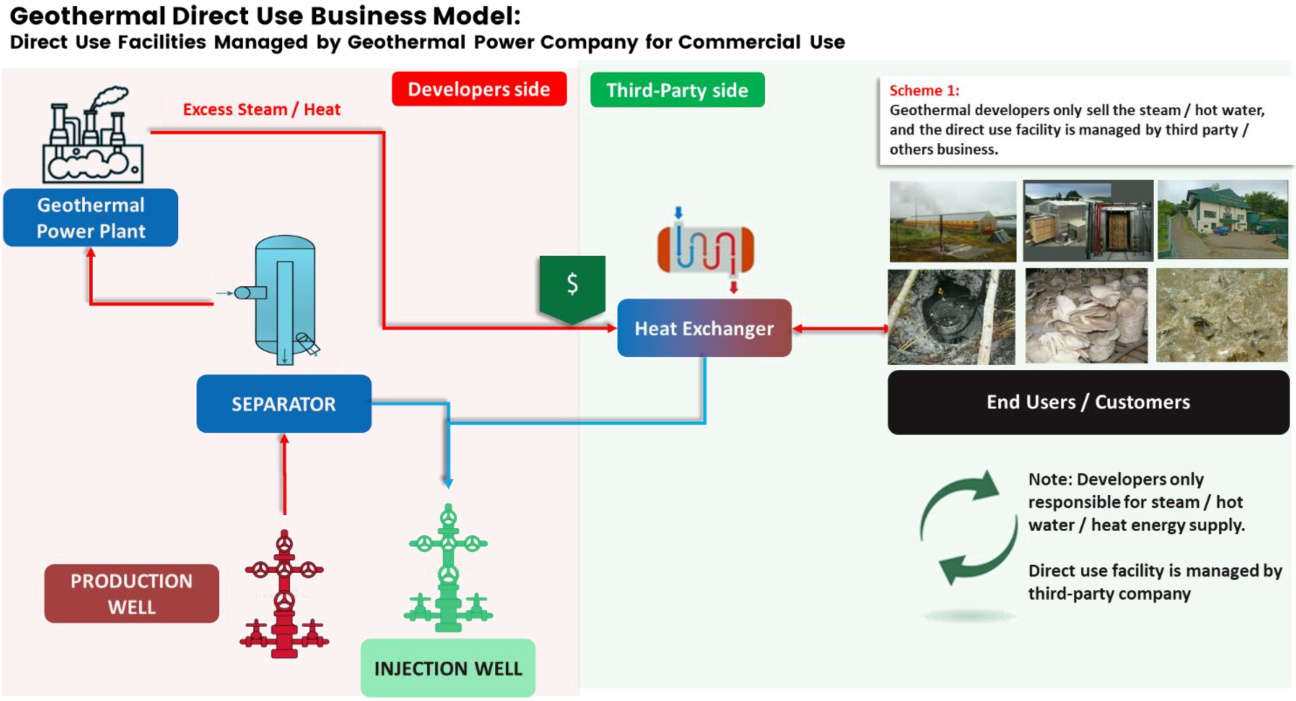

Figure 14: Illustration of direct use facilities managed by geothermal power company for commercial use when the Geothermal developers only sell the steam, and the direct use facility is managed by third party / other business.

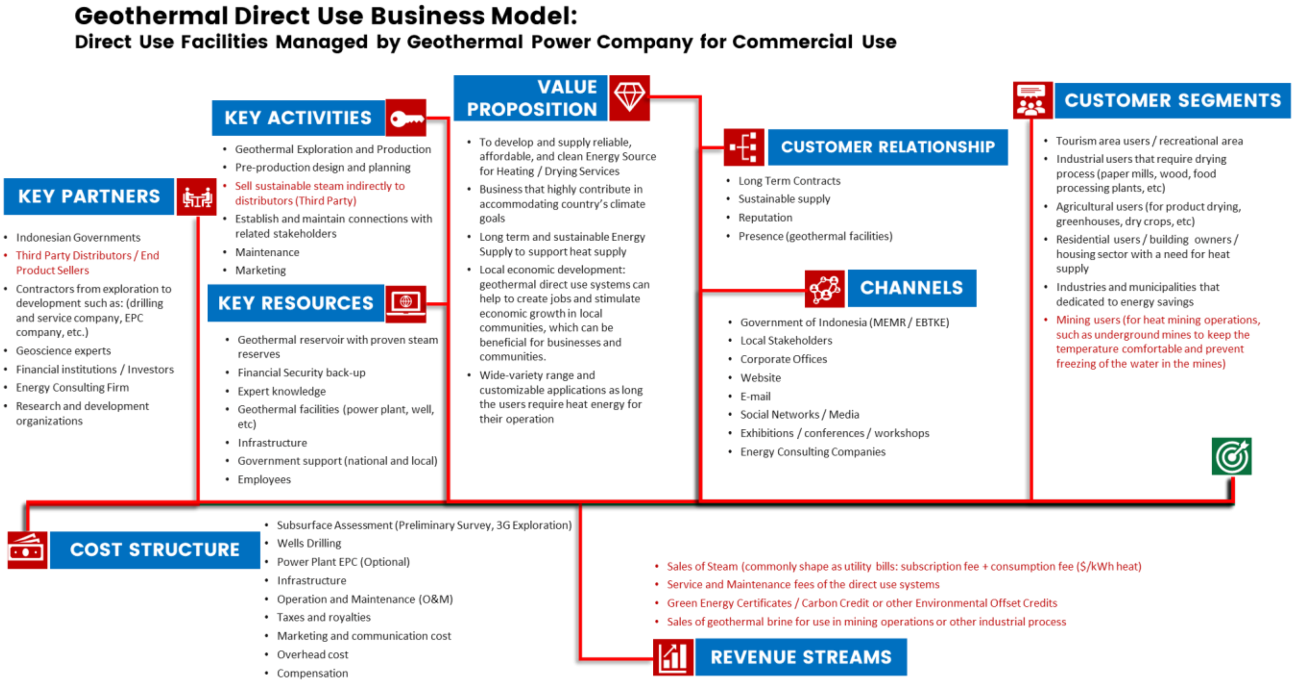

Figure 15: Typical business model of direct use facilities managed by geothermal power company for commercial use when the Geothermal developers only sell the steam, and the direct use facility is managed by third party / other business.

Scheme 2: Geothermal developers manage end-to-end direct use from extraction to application/sales.

This scheme of geothermal direct use generally refers to the comprehensive business of geothermal energy managed by developers involved in every aspect of the process. This includes everything from exploration and development to production and delivering end-use to customers. Essentially, these companies might be engaged in both power generation and direct use projects, handling the entire procedure from inception to completion.

In general, this scheme implements a fully integrated business model. This means that geothermal developers are accountable for all aspects of the direct use project, ranging from exploration and drilling to operating the facility or selling the produced energy to customers. The model enables the company to exert full control over the supply chain and the quality of the geothermal fluid, leading to better management of costs and revenue streams. It is often utilized for large-scale projects, where the developer has both the resources and expertise to manage the entire venture. However, this model also requires a substantial investment and risk-taking by the developer, as they must independently secure customers and finance the project.

One key advantage of this business model is the geothermal power company's ability to control the quality and reliability of the energy supplied. By overseeing the entire process, from production to delivery, the company can ensure that the energy is used efficiently and effectively. Furthermore, it can leverage its expertise in geothermal energy to offer technical support and consultation to its customers.

Another significant benefit of this model is its contribution to reducing greenhouse gas emissions and supporting sustainable development. Utilizing geothermal energy enables customers to decrease their dependence on fossil fuels and diminish their carbon footprint, aiding in climate change mitigation and the transition to a low-carbon economy.

End-to-end management of Direct Use facilities by a geothermal power company also opens opportunities for revenue diversification and growth. By making these facilities available to customers, the company can cultivate additional income streams, helping to counterbalance the costs of geothermal power generation. Moreover, by supplying a reliable and sustainable energy source, the company can attract new clients and broaden its customer base.

In the specific context of Indonesia, geothermal direct use managed, owned, and fully operated by geothermal developers presents a strategic choice. Developers can opt to run this business as part of their power companies or create a subsidiary as a special mission vehicle (SMV) to manage co-product businesses besides geothermal power generation, including the direct use business."

The illustration scheme of this direct use business model is shown in Figure 16 and the typical business model canvas is shown in Figure 17.

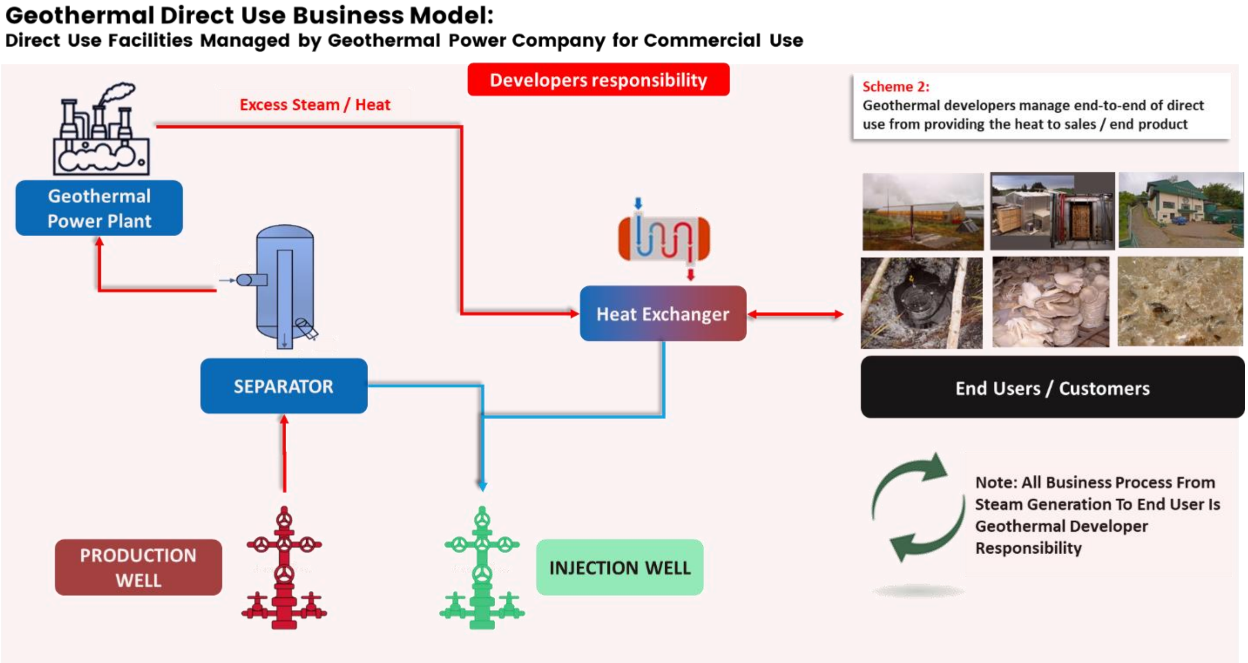

Figure 16: Illustration of direct use facilities managed by geothermal power company for commercial use when the geothermal developers manage end-to-end of direct use from extraction to application/sales.

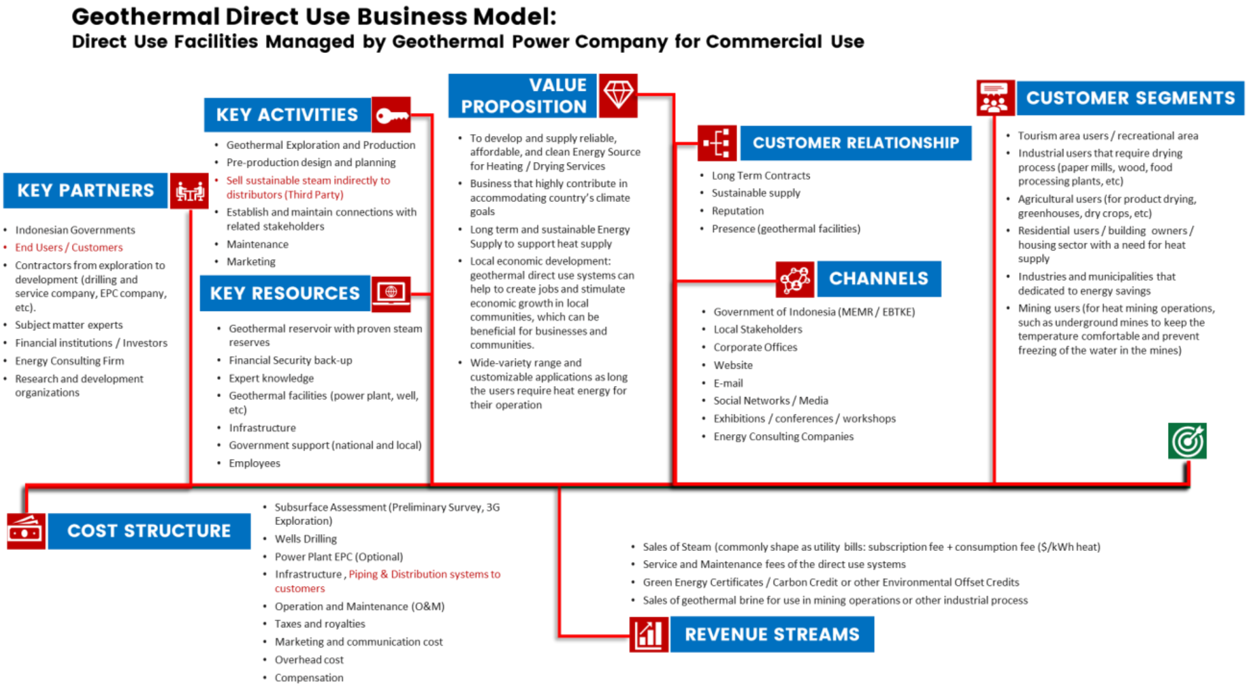

Figure 17: Typical business model of direct use facilities managed by geothermal power company for commercial use when the geothermal developers manage end-to-end of direct use from extraction to application/sales.

In short, the investigation of geothermal direct use business models reveals a promising avenue for geothermal power companies to extend their impact beyond electricity generation. The dual strategies of leveraging these resources for Corporate Social Responsibility (CSR) and commercial purposes exhibit significant potential. CSR-oriented initiatives underscore a commitment to sustainable practices and societal welfare, fostering community development while promoting environmental stewardship and social responsibility but the CSR might have minimum economic benefit to the company. Conversely, commercial exploitation of geothermal direct use, either through third-party management or end-to-end developer control, offers a pathway to revenue diversification and competitive advantage, capitalizing on the inherent sustainability of geothermal energy.

These business models serve not just as vehicles for economic growth, but also as catalysts for sustainable development, aligning with the United Nations Sustainable Development Goals. They illustrate how geothermal power companies can effectively harmonize their operational strategies with broader social objectives. The inclusive approach of CSR initiatives and the efficiency-driven focus of commercial endeavors both contribute to a more sustainable energy landscape, providing clean, reliable energy solutions. As such, these business models represent not only a strategic adaptation to market demands but also a conscientious move towards a more sustainable and socially responsible future.

3.3. Potential Opportunities and Challenges from related Geothermal Direct Use in Geothermal Developers' Side

Commercial geothermal direct use offers a promising path to leveraging natural resources for diverse applications. Careful planning, understanding of pros and cons, and learning from successful implementations can pave the way for broader adoption, contributing to energy efficiency, sustainability, and economic growth. From the geothermal developer's point of view, as shown in Table 2, there are several points that is require to be understand and prepared.

Table 2: The required study, pros and cons, and proven example mapping for geothermal direct use commercial application for geothermal developers.

Direct Use	Required Study	Pros	Cons	Proven example
Geotourism park and hot spring water Geothermal developers can develop integrated geotourism in conjunction with the location of the geothermal power plants (PLTP), and establish direct use facilities that can enhance the local economy around the PLTP	• A study on the tourism potential or visitors' potential for the area to be developed as a geotourism park. • A study of marketing strategies for introducing the geotourism park to the general public. • A feasibility study on the economic impact of direct use projects for geotourism on the core business of geothermal developers, through enhancing national and international reputation. • A detailed analysis of the project's impact on local health, safety, environment, and socio-economic aspects, along with the risks that may be faced during the development of facilities (risk assessment).	• Potentially become an icon for geothermal developers as the leading geothermal developer in Indonesia, and serve as one of the educational centers for renewable energy (especially geothermal) for the community. • Has the potential to enhance the economy since the pricing scheme can be negotiated directly with the beneficiaries in the industrial sector (not dependent on the ceiling tariff scheme). • Optimizes resources to produce derivative products with better selling prices compared to the ceiling tariff for electricity sales (Possibility to become a new revenue stream for geothermal developers). • Potentially be used as an educational tool for the community and to promote the advantages of geothermal energy such as clean energy, renewable and sustainable energy, etc. • It has the potential to increase the income of the local community collaborating in the development of the facilities of the geotourism park.	• Establishing a geotourism park with hot spring water amenities can involve significant investment in infrastructure development, maintenance, and ongoing operational costs. • Income from Geotourism does not necessarily have an significant direct impact on the revenue of geothermal developers. It is more likely to first affect the reputation, and then create a domino effect on stakeholders' confidence in the geothermal developer's business approach, which also prioritizes the enhancement of the local economy. • Finding a suitable location for geotourism park near surface thermal manifestations and/or geothermal power plant with sufficient space and access to build the facility complex might be problematic in terms of permitting, land acquisition, and access road	• Blue Lagoon, Iceland. This integrated geotourism facility is located next to Svartsengi geothermal power plant. • Whakarewarewa thermal village, New Zealand. This tourism cultural village facility Part of Rotorua geothermal field. • Waikita thermal spring, New Zealand.
In Integrated Geothermal Direct Use Facilities or Cascading Geothermal Direct Use Facilities, The geothermal energy is extracted from geothermal wells or	• A study on the potential offtakers/demand for heat energy in the targeted sectors (business potential, economic activities of local stakeholders that can cooperate by utilizing geothermal energy directly). • An economic analysis of the integrated direct use project on the	• There's potential for economic improvement since the pricing scheme can be directly negotiated with beneficiaries in the industrial sector (not dependent on the ceiling tariff scheme). • Resource optimization can yield derivative products with better selling prices compared to the ceiling tariff for electricity sales (This	• Establishing a geotourism park with hot spring water amenities can involve significant investment in infrastructure development, maintenance, and ongoing operational costs. • The permitting and concession process to local government might take longer time due to various different facilities to beinstalled, thus may require different	• Geothermal Industrial Park Cascaded Use for supplying heat energy for various company in Hellisheiði – Iceland (ESMAP, 2022)

Direct Use	Required Study	Pros	Cons	Proven example
excess steam can be distributed through a network of pipelines to different users or facilities. The highest temperature and pressure geothermal fluid is first used for high-temperature applications, and then the lower temperature and pressure fluid is cascaded for lower-temperature applications. This allows for multiple uses of geothermal heat before the fluid is eventually reinjected into the reservoir Geothermal Developers can develop integrated geothermal direct use near the location of geothermal power plants (PLTP), and establish direct use facilities that can enhance the economy in the vicinity of the PLTP.	core business of geothermal developers, through enhancing national and international reputation. • A study on the social aspects of development planning as a basis for social engineering to ensure the project can run smoothly. • A detailed analysis of the project's impact on local health, safety, environment, and socio-economic aspects, along with the risks that may be faced during the development of facilities (risk assessment).	has the potential to become a new revenue stream for geothermal developers). • Cascaded use of heat energy from the geothermal power plant can create multiple income streams and aid in harnessing the underutilized natural resource. • It can be used as an educational tool for the community and to promote the benefits of geothermal energy, such as clean energy, renewable and sustainable energy, and more.	permitting process from more than one offices or instances in province or district level. • Finding a suitable location near surface thermal manifestations or geothermal power plant with sufficient space and access to build the facility complex might be problematic in terms of permitting, land acquisition, and access road (Especially if the industry that will be cooperated or become partnerships does not have a factory/industrial building close to the location of the geothermal power plant)	• Wairakei and Rotorua, Geothermal Power Station in New Zealand uses cascading geothermal systems to provide both electricity generation and direct use applications, including industrial processes and agricultural activities.

4. CONCLUSION

Geothermal direct use in Indonesia holds great potential for sustainable energy solutions. This research explores its diverse applications and business models, shedding light on how the country can tap into geothermal resources for a cleaner future. Geothermal direct use can lower emissions, ensure energy security, and drive economic growth. Collaboration among stakeholders, including policymakers, investors, and communities, is essential for success. In Indonesia, a country with vast geothermal resources, the opportunities for leveraging geothermal direct use are particularly pronounced. However, realizing this potential requires a concerted effort across multiple dimensions:

- Technological Innovation: Continuous investment in R&D, technology adaptation, and integration will drive efficiency and effectiveness in GDU applications.
- Regulatory Support: Crafting supportive policies and simplifying compliance processes are crucial for facilitating GDU development.
- Economic Viability: Developing a robust financial framework that includes diverse funding options and public-private partnerships can ensure the economic success of GDU projects.
- Social and Environmental Responsibility: Emphasizing community engagement, environmental stewardship, and alignment with sustainability goals underscores the broader positive impact of GDU.
- Adaptable Business Models: Moving beyond CSR-based models and creating adaptable and scalable business models will foster sustainable growth in the GDU sector. By embracing applicable models, utilizing geothermal sites, and addressing challenges, Indonesia can unlock this potential for a greener, more prosperous future.

5. PATH FORWARD AND RECOMMENDATIONS

While this paper sheds light on the potential of geothermal direct use applications in Indonesia, there are avenues for further research and recommendations that can propel the nation towards a more sustainable and energy-efficient future. Building upon the insights presented, there are several paths forward about future research and offer recommendations to guide stakeholders in advancing the adoption of geothermal direct use as follows:

- Comprehensive Feasibility Studies: Future research should encompass in-depth feasibility studies for specific geothermal direct use projects. These studies should consider technical, economic, social, and environmental aspects to provide a holistic understanding of project viability.
- Technological Innovation: Research into innovative technologies can enhance the efficiency and cost-effectiveness of geothermal direct use applications. Advancements in heat exchange systems, temperature control, and distribution networks can drive implementation.
- Stakeholder Engagement: Engaging communities, end-users, and local authorities is pivotal. Future research could delve into effective engagement strategies that promote local ownership, knowledge sharing, and collaboration for successful project implementation.
- Policy Framework Enhancement: Developing clear and supportive regulatory frameworks is essential. Research could focus on assessing existing policies and recommending improvements that facilitate geothermal direct use projects.
- Financial Mechanisms: Exploring financing mechanisms, including incentives, subsidies, and financing options, can encourage private sector involvement and reduce financial barriers for geothermal direct use projects.
- Capacity Building: Strengthening technical expertise through capacity building initiatives and knowledge exchange programs can empower local communities and professionals to actively contribute to geothermal direct use projects.
- Collaborative Research**:** Collaborative research endeavors between academia, industry, and government can drive innovation and provide actionable insights for effective geothermal direct use implementation.

The following recommendations are proposed for consideration by relevant stakeholders to foster the growth of geothermal direct use (GDU) in the energy sector:

- **Establish a Geothermal Direct Use Task Force**:

  The government could create a dedicated task force for direct use. This team would have a mandate to streamline regulatory frameworks, facilitate knowledge exchange among experts, and promote the broader adoption of GDU applications. Such a task force could serve as a central body to coordinate efforts and drive cohesive policymaking.

- **Conducting a Preliminary Study on Market Demand:**

  A comprehensive analysis of the market demand for direct-use geothermal resources in and around active geothermal fields is critical. Understanding market needs is a strategic approach to attracting investors and developers by demonstrating potential economic viability.

- **Promotion of Public-Private Partnerships (PPPs) and Commercial Projects:**

  The fostering of PPPs can tap into the expertise, resources, and innovative capabilities of the private sector. This collaboration is essential in expediting the development and implementation of geothermal direct use projects.

- **Creation of Incentive Mechanisms:**

  There is a need to implement financial incentives and supportive policies that make investment in GDU more attractive. Such mechanisms could be pivotal in accelerating the initiation and success of geothermal projects.

- **Simplification of Licensing and Compliance Processes:**

  Streamlining the licensing procedures is necessary to minimize entry barriers. Providing comprehensive guidelines and assistance for compliance can enhance understanding and adherence to regulatory requirements, fostering a more conducive environment for project development.

- **Emphasis on Capacity Building:**

  It is crucial to prioritize education and training initiatives that enhance technical expertise related to GDU. Cultivating a knowledgeable and skilled workforce is fundamental to the industry's growth and sustainability.

- **Encouragement of Hybrid Business Models:**

  There is an opportunity to support the development of versatile business models that integrate both traditional and innovative practices. Customizing these models to local contexts and cultural nuances can ensure their relevance and acceptance.

- **Move Beyond CSR-Based Models for Scalability:**

  Explore alternative models that enable scalable, profitable and sustainable GDU development. Balance profitability with social and environmental goals.

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